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Lab 1 part 2 Introduction to HYDRA as a tool to view multispectral data and cloud detection.

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Table: MODIS Channel Number, Wavelength (μm), and Primary Application

Reflective Bands			Emissive Bands		
1,2	0.645, 0.865	land/cld boundaries	20-23	3.750(2), 3.959, 4.050	sfc/cld temperature
3,4	0.470, 0.555	land/cld properties	24,25	4.465, 4.515	atm temperature
5-7	1.24, 1.64, 2.13 "		27,28	6.715, 7.325	water vapor
8-10	0.415, 0.443, 0.490	ocean color/chlorophyll	29	8.55	sfc/cld temperature
11-13	0.531, 0.565, 0.653	"	30	9.73	ozone
14-16	0.681, 0.75, 0.865	"	31,32	11.03, 12.02	sfc/cld temperature
17-19	0.905, 0.936, 0.940	atm water vapor	33-34	13.335, 13.635,	cld top properties
26	1.375	cirrus clouds	35-36	13.935, 14.235	cld top properties

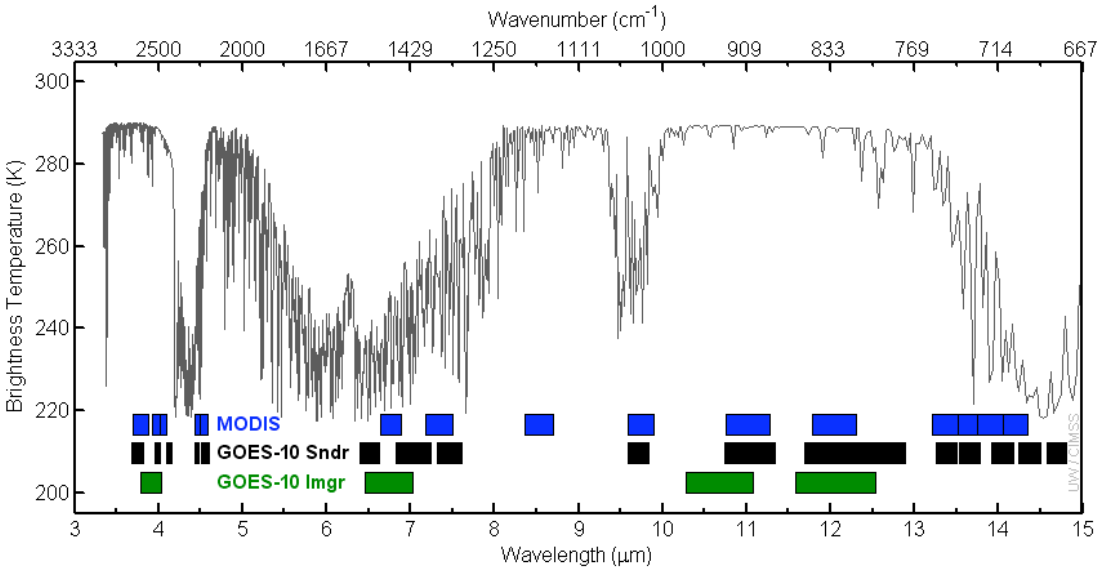

Figure 1: Infrared brightness temperatures for a standard atmosphere over the infrared window along with MODIS, GOES-10 Sounder and GOES-10 Imager bandwidths.

1. Inspect the scene over the coastal waters of Brazil on 27 March 2004 detected by MODIS using HYDRA (see the attached instruction sheet explaining how to run HYDRA). After starting up HYDRA the HYDRA window appears (Figure 2). To load a MODIS Level-1B 1KM file from disk, click on "Load | Local Data" and select the file to be loaded (e.g., MYD021KM.A2004087.1630.005.2007252102626.hdf). When the file is loaded, an image of the 11 μm radiances appears, as shown in Figure 3.

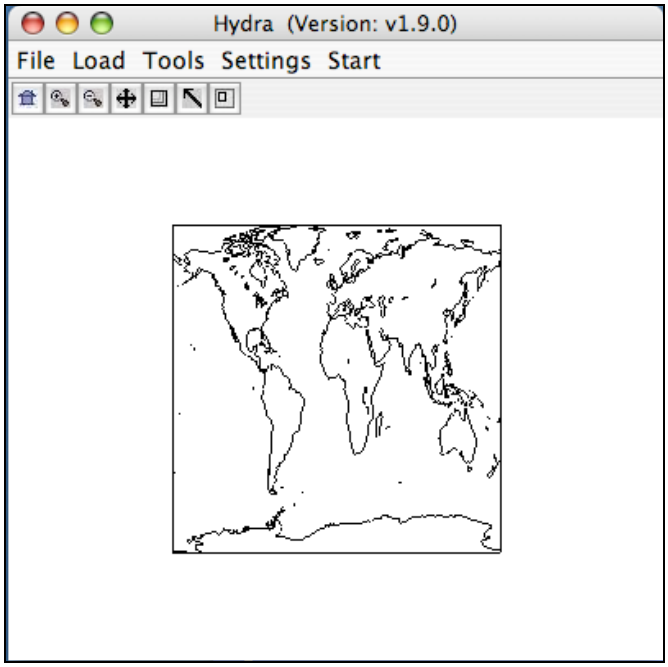

Figure 2: The HYDRA window.

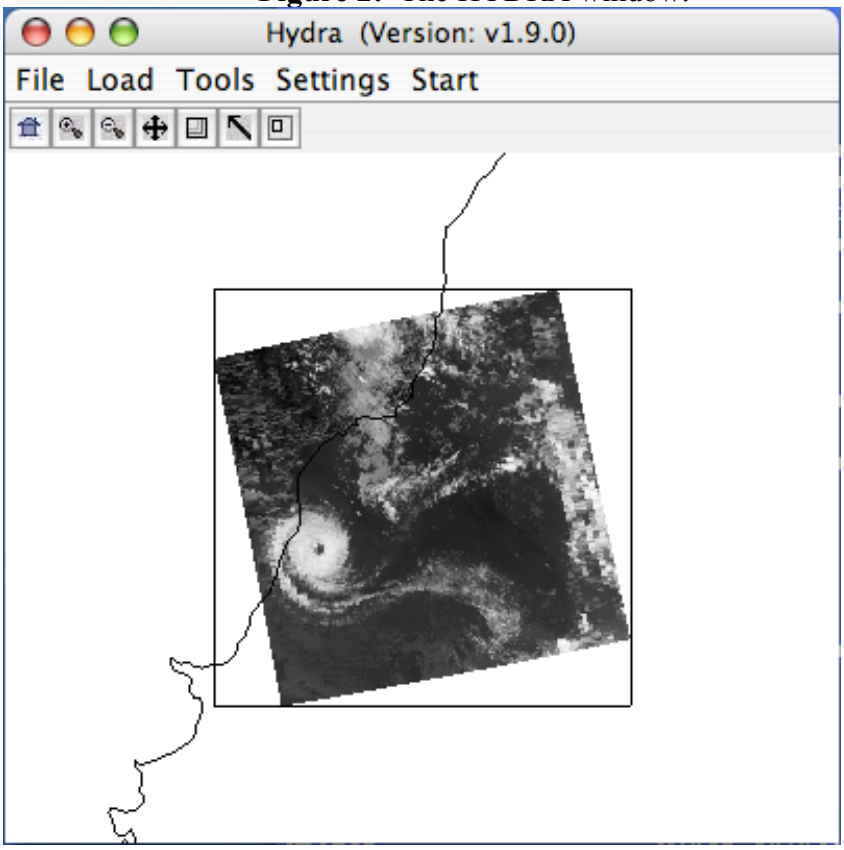

Figure 3: HYDRA window with a MODIS L1B 1KM file loaded.

2. Get familiar with the command menu ***Settings***. Band 31 (11 μm) is automatically displayed at reduced resolution. Try different black and white enhancements by adjusting the color range (***Set Color Range***). Use the toolbar at the top to zoom in and zoom out and translate the image. Reset the image. Display the image in color and try different color enhancements.

3. ***Start*** the ***Multi-Channel Viewer***. Display the data at full resolution by selecting a subset of the data displayed in the Hydra window (right most icon in toolbar in the Hydra window). The one kilometer resolution data will appear in the Multichannel Viewer window (see Figure 4). Zoom in on the tropical cyclone off of the Southeast Coast of Brazil in both the Multi-Channel Viewer window and in the Hydra window – compare the resolution in the images. Use the arrow icon at the bottom of the Multichannel Viewer window to examine values in the full resolution image – locate the lat & lon of the min and max brightness temperature values in the image.

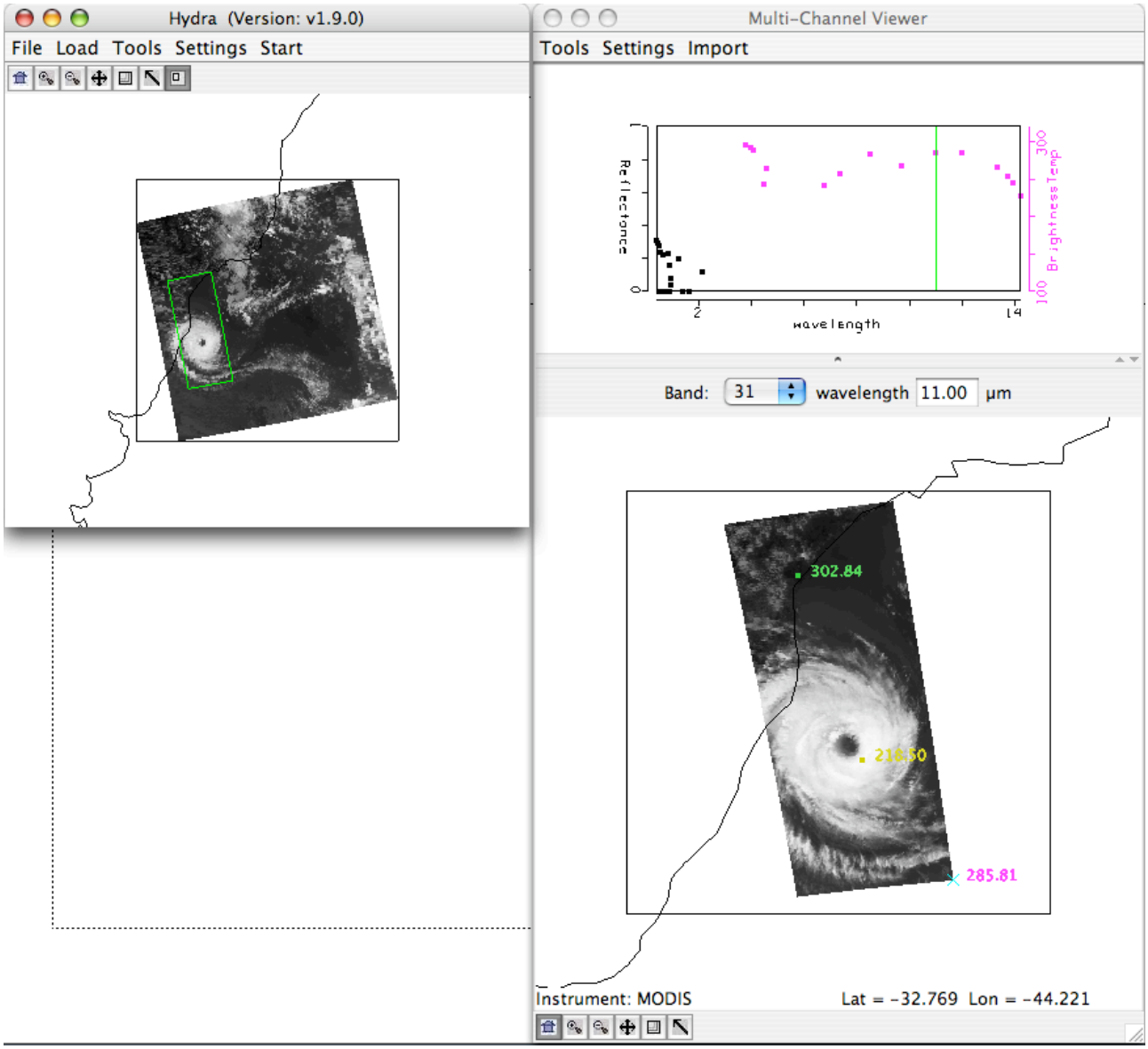

Figure 4: One kilometer resolution data displayed in the Multichannel Viewer window.

4. Now change to **Band number** 2 (.86 micron). Zoom in on the Northern portion of the cyclone and the clear Brazilian coast North of the cyclone. Change the projection to Instrument (**Settings->Projections->Instrument**). You may have to re-center the image. Figure 5 shows this portion of the image. What features that you see along the coastline and the clouds are caused by the instrument? How do you know this? How did these change when you changed the projection? What other features do you see in this band over the brightest (highest reflectance) clouds? What is the cause of the black features? When you are finished, change the projection back to Lambert Equal Area.

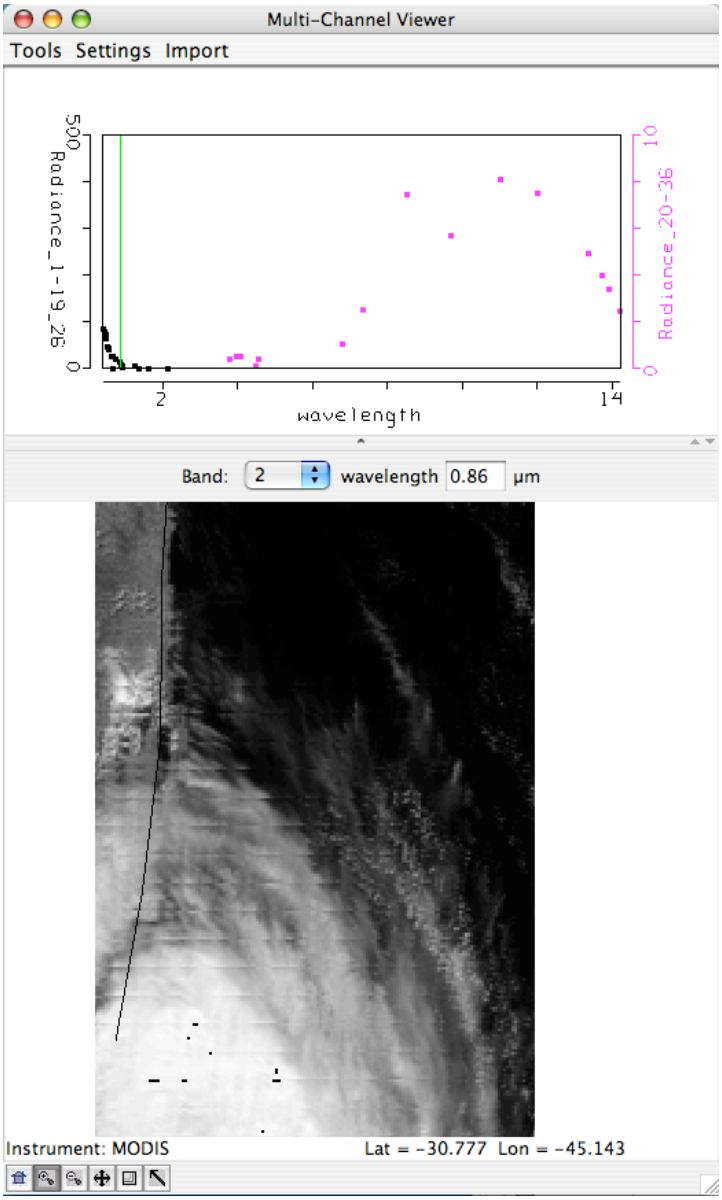

Figure 5: Hydra display over the Northern portion of the tropical cyclone cloud shield and Brazilian coast.

5. Now chose ***File->Exit*** from the main HYDRA window and restart and reload the same MODIS file again so that we can get another reduced resolution view of the entire MODIS granule. Open a new Multi-Channel Viewer. Cloud detection techniques normally use a combination of individual spectral tests to determine if an individual field of view is obstructed by cloud or not. Investigate the brightness temperatures and reflectances emanating from the land, ocean and cloud scene in different wavelengths; make sure you look at Bands 1 (0.65 µm), 2 (.86 µm), 26 (1.38 µm), 6 (1.64 µm), 7 (2.1), 20 (3.8 µm), 27 (6.5 µm), 31 (11 µm) and 35 (13.9 µm).

(a) Comment on the cloud and clear sky characteristics in each of these spectral bands.

(b) Which three bands would you choose to determine a cloud / no cloud "mask"; why?

6. Now select ***Linear Combinations*** from the ***Tools*** menu at the top of the Multi-Channel Viewer window. A new window (***Channel Combinations Tool***) will open. You can create combined channel images and scatter plots which can be used to investigate the scene and infer atmospheric and surface properties by selecting the channels and mathematical operations located at the bottom of the window. To select a channel, you can either type the wavelength into the equation boxes at the bottom or move the colored bars to the desired wavelength using the ***Grab*** tool (***Arrow***) on the main toolbar and holding down the right mouse button while located on the color bar. Try the following band combinations to create combined images (once the channels and operations are correctly selected, click on the ***Compute*** button), and indicate the advantages and disadvantages of each combination for cloud detection. Set the color scale to Color (the default is inverse grey). Set the Color Range limits to values you would use for cloud detection

- Band 20 (3.80 μm) – Band 31 (11 μm) (Brightness Temperature)
- Band 29 (8.6 μm) - Band 31 (11 μm) (Brightness Temperature)
- Band 2 (0.86 μm) / Band 1 (0.650 μm) (reflectance)

(a) Create a single band image of Band 31 in the Linear Combinations window (select a single band by choosing a blank in the mathematical operations drop down menu). Map each linear combination on the Y-axis (by clicking the Y axis button) against Band 31 (11.0 μm) on the X-axis (by clicking the X-axis button). Click on ***Scatter*** to open a scatter plot window (an example is given in Figure 6). Estimate what threshold values you would use in each test to indicate the presence of clouds? Select different regions in the scatter plot window and look at the corresponding points in the linear combination window. Make the Scatter Diagram window large so that you can see patterns that emerge. Does this help to refine the threshold values you chose in question 6?

(b) Close the ***Linear Combinations Tool*** window. Now load the MODIS cloud mask image (MYD35_L2.A2004087.1630.005.2007252104816.hdf) from the main Hydra window. The 4 category cloud mask will be overlaid on the Multi-Channel Viewer image and a new cloud mask window will be opened. Please note that the highest confident clear category (green) is not displayed, you will see the underlying image for this category. You can use the button at the bottom to toggle the mask off and on to see how well it performed. Look at some small regions at full resolution and see how well it performed. Find a location where you do not think it is performing well and explain why.

7. How can understanding cloud detection strengths and weaknesses improve:

- Operational forecasts?
- Cloud Research?
- Our understanding of Global Climate Change?

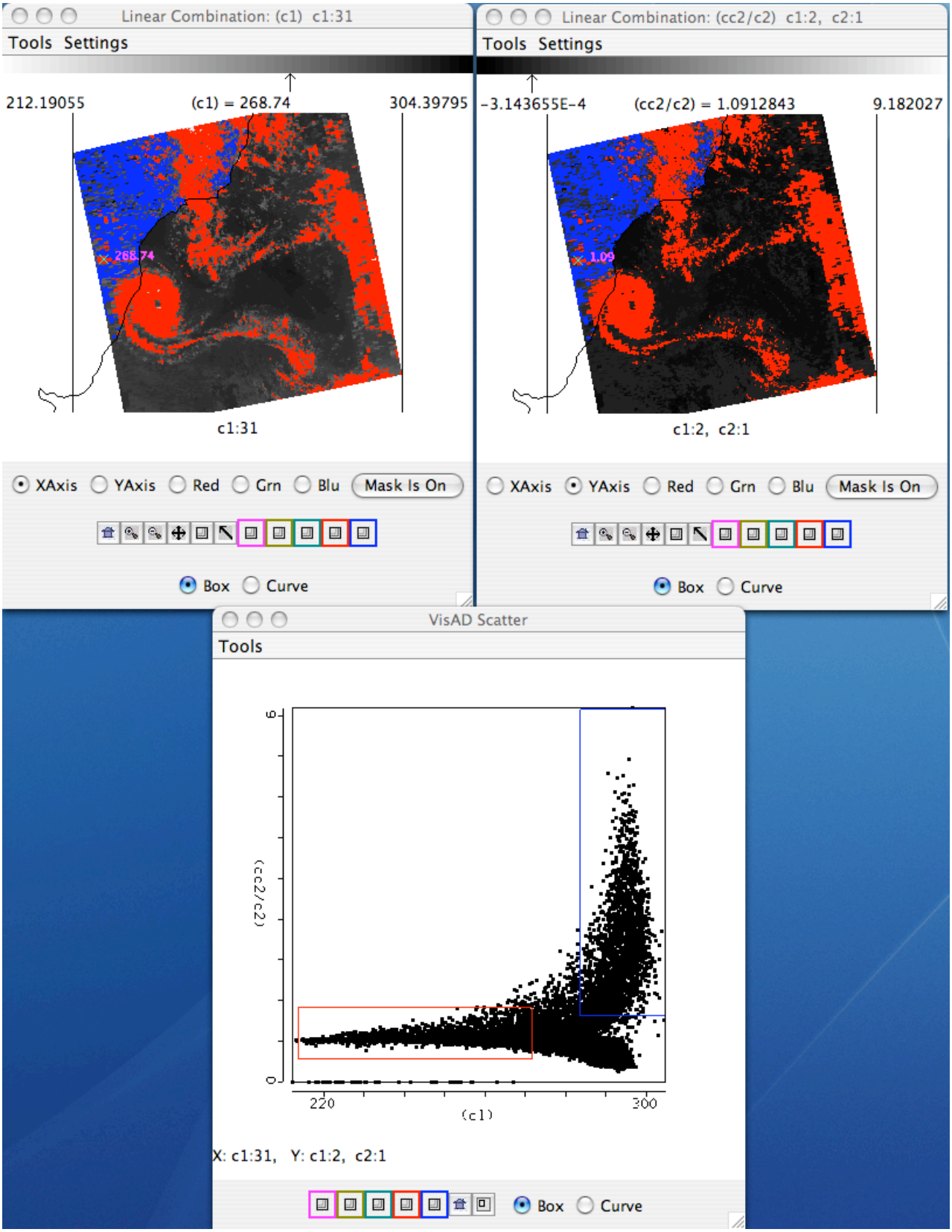

Figure 6: Band 31 (11 micron) and (Band 2 (.86 micron) – Band 1 (.65 micron)) individual band images (top panels) as displayed using the Linear Combinations Hydra tool. A scatter diagram of the (Band 2 (.86 micron) – Band 1 (.65 micron)) reflectances versus the Band 31 Brightness Temperatures are displayed in the bottom panel. This scene is from 27 March 2004.

Appendix –Summary of HYDRA Commands

HYDRA main window
Displays a world map and shows ***File, Load***, ***Tools, Settings***, and ***Start*** at top.

File offers
New to open a new main HYDRA window
Exit ends the entire HYDRA session

Load has the options
Local Data allows you to search local directories to find MODIS, AIRS, GOES or Meteosat data.
Remote Data allows you to get data from a remote server (a) Terra or Aqua Direct Broadcast or (b) Goddard DAAC
GOES/MSG allows you to get geostationary satellite data from an ADDE server
Calipso allows you to display CALIPSO lidar data
CloudSat allows you to display CLOUDSAT data
AREA allows you to load data in McIDAS AREA file format

After a data granule is selected HYDRA displays the infrared window (at reduced resolution 4 km for MODIS) on a world map.

Tools offers
Capture Display to save the image as a jpeg

Settings has
Set Color Range where the histogram of brightness temperatures or radiances can be adjusted to maximize contrast – the color range can be altered with a right click plus drag at either end of the color scale
Set Color Scale where ***Color***, ***Gray*** and ***Inverse Gray*** gives choice of color, grey, or inverse grey (which produces white clouds for infrared channels)

The toolbar at the top enables reset, zoom in, zoom out, translate, box magnify, find location, and subset at full resolution functions
Reset (left click on reset and then click on image to restore original image)
Zoom in (left click on zoom in plus click on image enables enlargement)
Zoom out (left click on zoom out plus click on image enables far view)
Translate (left click on translate plus click on image enables moving the image within the window)
Box magnify (left click on box plus click and drag to create box for enlargement)
Find location (left click on arrow plus click on image displays location of the chosen pixel)
Subset at full resolution (only after Multi-Channel Viewer is engaged, then left click on subset plus click and drag on image creates a subset of image at full resolution; this is automatically transferred from HYDRA into the Multi-Channel Viewer when both are engaged – data is displayed at reduced resolution by default unless subset function is used)

Start opens ***Multi-Chanenel Viewer***

wherein the measured spectra (wavelength on x-axis and radiance or brightness temperature on y-axis) is displayed along with a spectral band superimposed on a map. Left click on arrow icon in the bottom toolbar allows you to see the pixel value for a given lat-lon (using left click and drag).

Tools menu (appears in ***Multi-Channel Viewer*** window)

Linear Combinations opens the **Channel Combination Tool** display where you can specify linear combinations of spectral bands a,b,c and d (a +-x / b) +-x / (c +-x / d).

rgb allows you to select a spectral channel for each color in the RGB display

Transect allows you to create a line on the image and see the temperatures or radiances along the transect marked by shift plus right click and drag.

Capture Display allows you to save the image as a jpeg

Statistics displays the min and max values in the image

Reference Spectrum allows you to compare spectral measurements from two selected pixels (controlled by the arrows in the bottom toolbar)

Settings (on the Viewer) has

Set Color Range where the histogram of brightness temperatures or radiances can be adjusted to maximize contrast – the color range can be altered with a right click plus drag at either end of the color scale

BT->radiance allowing you to toggle from brightness temperatures to radiances in the infrared spectral channels

Projection offers ***Lambert Equal Area, Polar Stereographic*** or ***Instrument*** projections of the data

Set Color Scale where ***Color***, ***Gray*** and ***Inverse Gray*** gives choice of color, grey, or inverse grey (which produces white clouds)

Lat/Lon Grid can be superimposed on the image by using the toggle

Image Label labels the image with the instrument and day/time of the data

The ***Channel Combination Tool*** offers the usual tool bar and

Compute to create an image of the selected linear combination (you can indicate at the bottom your preference for this linear combination to be on the x- or y-axis in the scatter plot) and displays a toolbar for image manipulations (five color boxes are available in the toolbar to select regions by boxes or curves in the image that will be displayed in the scatter plot; a left click drag in the image highlights the chosen points in the scatter plot).

Scatter creates a scatter plot of the chosen x- and y-axis linear combinations. Five color area boxes (or area curves) in the bottom toolbar of the scatter plot allow you to select points in the scatter plot that will be displayed in the x-axis and y-axis images; a left click drag in the scatter plot highlights the chosen points in the scatter plot and simultaneously in the x- and y-axis images. Conversely (as indicated before) left click drag in the x- or y- axis images shows the locations of the chosen pixels in the scatter plot. Each color area box (or area curve) can be erased with a left click when the color box is engaged; after erasure another area box (or area curve) can be selected for this color. The zoom capability in the scatter plot (on the

bottom right of the toolbar) allows you to enlarge special features in the scatter plot and investigated them in more detail.

Viewing Level 2 Products

When viewing level 2 products (staged in a separate file), HYDRA generates a display of that product. Current choices include the cloud mask (from MOD35), total column ozone and water vapor (from MOD07), cloud top properties (from MOD06), fires from (MOD14) and AIRS profile retrievals (generated using a statistical regression retrieval algorithm trained with AIRS spectra calculated from radiosonde observations).

When viewing MOD07 or AIRS profiles, ***Variables*** offers the choice to display

air temperature profiles
total ozone
precipitable water
surface temperature
water vapor profiles
surface pressure
ozone profiles

Levels offers 17 levels between 1100 and 50 hPa for the retrieval field display.

Settings offers a choice to ***Set Color Range***, ***Set Color Scale***, and ***Show Color Bar***. The last choice enables superposition of a color bar label that identifies the values of the product associated with each color.

Tools offers the option of ***Reference Profile*** that allows you to compare level 2 products from two selected pixels (controlled by the arrows in the bottom toolbar where the red dot indicates the location of the second profile) and ***Transect*** that allows you to construct a transect across the level 2 product image.